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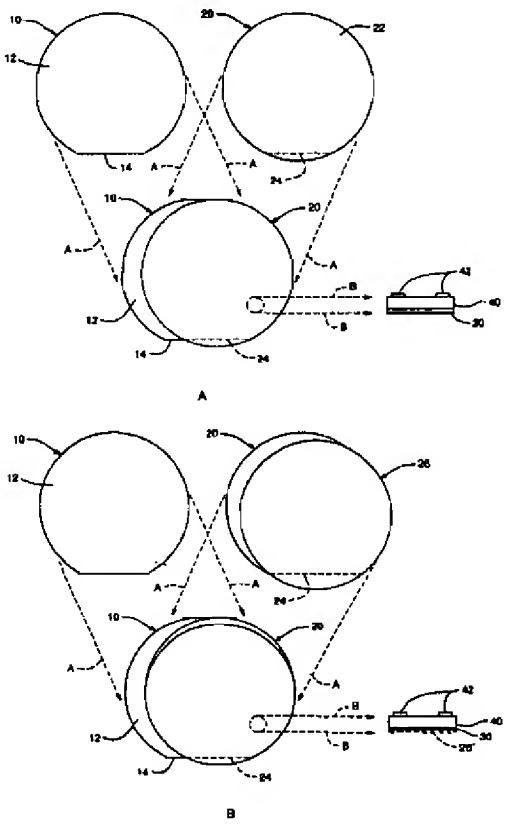
(54) Title: WAFER LEVEL APPLICATION OF TACK-FREE DIE-ATTACH ADHESIVE FILM



(57) Abstract: A tack-free film (20) of die-attach adhesive is tacked to a semiconductor wafer (10) at the wafer level and the wafer is thereafter excised into individual semiconductor die (40) each having a tack-free die-attach adhesive preform (30) thereon. The die may be tacked to an electronic package (110) or substrate by the die-attach adhesive preform and does not need to be clamped in place during subsequent curing. The die-attach adhesive is dry to the touch, i.e. tack-free in its dry or B-staged condition and includes both thermosetting and thermoplastic adhesive, may be insulating, electrically conductive, anisotropic electrically conductive and/or thermally conductive, and may include a sacrificial layer.

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WAFER LEVEL APPLICATION OF TACK-FREE DIE-ATTACH ADHESIVE FILM

This Application is a continuation-in-part of U.S. Patent Application Number 09/613,349 filed July 11, 2000, and claims the benefit of U.S. Provisional Application Serial Number 60/164,241 filed November 8, 1999, of U.S. Provisional Application Serial Number 60/196,243 filed April 10, 2000, of U.S. Provisional Application Serial Number 60/196,652 filed April 12, 2000, and of U.S. Provisional Application Serial Number 60/_____ entitled "Wafer Level Pre-Application of Tack-Free Die-Attach Adhesive Film Rev. E, August 3, 2000" filed by Kevin Kwong-Tai Chung on or about August 4, 2000.

The present invention relates to the application of die-attach adhesive and, in particular, to the application of a tack-free die-attach adhesive.

Since the adoption of epoxy for attaching semiconductor dies to electronic substrates in the early 1970's in place of eutectic materials, silver-filled conductive epoxy pastes have been the primary material used. Insulating die-attach adhesive pastes have been used where required by the specific application. Die-attachment has traditionally followed a process of dispensing epoxy adhesive onto the electronic substrate or package that is to receive a semiconductor die, placing the individual semiconductor die into the dispensed adhesive, and curing the adhesive by applying heat to the assembled substrate, die and adhesive..

Uses of film adhesive or adhesives other than pastes for die attachment have been relatively few and not well documented. One usage that is relatively well known is the use of a fast-setting or fast-bonding film carrier that cures rapidly at a high temperature and that is on a base material such as a polyimide film, typically for attaching memory chips on what is known as a "lead-on-chip" package. Such film adhesive is induced to flow and bond within seconds at a temperature as high as 275 - 350°C depending on the adhesive used. Typically, such film adhesive is supplied in reel format of the desired dimension, individual pieces of film adhesive are excised therefrom, semiconductor die are placed on the individual adhesive film

with suitable applied heat and pressure to flow the adhesive and, if necessary, cure the adhesive. In other cases, the film adhesive are made into preforms of the required size(s), and are placed between the die and substrate with suitable applied pressure and heat to flow and bond the die to the substrate.

Most conventional attachments of semiconductor die using film adhesives require a special pressure clip or fixture to properly position and hold the die against the substrate to allow proper curing and achieve reliable adhesive bonding between the die and the substrate.

U.S. Patent 4,793,883 disclosed describes partially curing an adhesive to a non-tacky state and U.S. Patents 5,411,921 and 5,110,388, for example. disclose a method of placing wet or tacky preformed adhesive onto the back side of the semiconductor wafer and subsequently B-staging the adhesive to a tack-free condition. Because the adhesive is wet and/or tacky when applied to the semiconductor wafer, it is difficult to handle and so these methods are very difficult to control and are not known to have found widespread commercial application.

Subsequently, U.S. Patent 5,177,032 describes another method of die attachment on which a fast-setting epoxy adhesive film is coated on a Kapton film. These film adhesives and many others require that the equipment or tooling for placing the semiconductor die onto a substrate maintain a certain pressure between the die and the substrate at an elevated temperature until the adhesive gels-up to a substantially cured state sufficient to retain the die in the desired position on the substrate before releasing the die and substrate for post-curing the adhesive. This requirement tends to tie-up the pick-and-place machines and other equipment utilized in an in-line process, unless batch processing utilizing special fixtures for applying proper pressure during curing or utilizing special pressure-clips to maintain pressure during curing, both of which reduce production and add expense. If proper pressure is not maintained, the die will move and voids will be created along the bond line, thereby to cause unsatisfactory and/or unreliable bonding.

In addition, the temperature needed to so cure the adhesive tends to be high, e.g., 200°C or higher, and the time therefor also tends to be long, e.g, as long as 10-60 seconds. A disadvantage of such methods arises because the higher curing

temperature, such as 200°C or higher, tends to build up mechanical stress during cooling in the bonding cycle due to any difference in the coefficients of thermal expansion of the semiconductor die, the adhesive and the substrate, which can adversely affect the reliability and integrity of the attachment of the die to the lead frame. For example, for one lead-on-chip packaging of memory devices as used by IBM and others, curing of the epoxy must be made at the very high temperature of 275-350°C so that the time that pressure must be applied by the bonding equipment may be reduced to a few seconds. But such high temperature has the short coming of inducing excessive stress upon cooling and so is more suitable for smaller semiconductor devices, or at least devices where one of the die dimensions is relatively small. Where the semiconductor die is to be utilized at or cycled to a cold temperature, for example, -55°C for military and aerospace applications, the thermally induced stress problem is exacerbated.

Accordingly, there is a need for a dry, tack-free and film-based adhesive semiconductor die attachment wherein the adhesive can preferably be pre-laminated onto a semiconductor wafer to eliminate the expense of individually applying die-attach adhesive individually to the excised semiconductor die. Perhaps even more importantly, there is a need for an adhesive film die attachment that flows and forms at least a temporary bond immediately upon placement of the semiconductor die so that the required time and expense of the pick-and-place machine can be reduced, preferably to as short as a few seconds or more preferably to less than one second. It is also desirable that the position of the die on the substrate not change significantly during the subsequent curing of the film adhesive to its fully cured solid state, even where no tool or fixture holds the die in such position during curing. Ideally, such a film adhesive should have a fast bonding characteristics much like that of a plastic molten state instead of like a high-viscosity liquid paste.

To this end, the present invention comprises a method for making a semiconductor die having a tack-free die-attach adhesive preform thereon comprising:

providing a film of tack-free die-attach adhesive;

placing the film of tack-free die-attach adhesive against a semiconductor wafer;

heating at least the tack-free die-attach adhesive film and tacking the tack-free die-attach adhesive film to the semiconductor wafer; and

excising the semiconductor wafer and the tack-free die-attach adhesive preform tacked thereto into individual semiconductor die each having a portion of the tack-free die-attach adhesive film tacked thereto.

BRIEF DESCRIPTION OF THE DRAWING

The detailed description of the preferred embodiments of the present invention will be more easily and better understood when read in conjunction with the FIGURES of the Drawing which include:

FIGURE 1 is a plan view schematic diagram illustrating a semiconductor wafer, an exemplary wafer-level tack-free film, and the juxtaposition thereof, according to the invention;

FIGURE 1A is a plan view schematic diagram illustrating a semiconductor wafer, an alternative exemplary embodiment of a wafer-level tack-free film, and the juxtaposition thereof, according to the invention;

FIGURE 2 is a plan view schematic diagram illustrating an alternative exemplary embodiment of a tack-free film according to the invention;

FIGURES 3A and 3B are plan view and side cross-sectional view schematic diagrams, respectively, of an alternative exemplary embodiment of a wafer-level tack-free film according to the invention;

FIGURE 4 is a side cross-sectional schematic diagram of an exemplary attachment of an electronic device to an electronic substrate employing the alternative exemplary embodiment of a wafer-level tack-free film of FIGURES 3A and 3B;

FIGURE 5 is a side cross-sectional schematic diagram of an exemplary attachment of an electronic device to an electronic substrate employing the alternative exemplary embodiment of a wafer-level tack-free film of FIGURE 1 or 2;

FIGURE 6A is a plan view schematic diagram of an exemplary holder for a semiconductor wafer and FIGURE 6B is a side cross-sectional schematic diagram of the holder of FIGURE 6A with a wafer therein;

FIGURE 7 is a plan view schematic diagram of an alternative embodiment of

an exemplary wafer holder; and

FIGURE 8 is a side view schematic diagram of a wafer carrier having a wafer mounted in the exemplary holder of FIGURE 6A or 7 therein.

In the Drawing, where an element or feature is shown in more than one drawing figure, the same alphanumeric designation may be used to designate such element or feature in each figure, and where a closely related or modified element is shown in a figure, the same alphanumerical designation primed may be used to designate the modified element or feature. Similarly, similar elements or features may be designated by like alphanumeric designations in different figures of the Drawing and with similar nomenclature in the specification, but in the Drawing are preceded by digits unique to the embodiment described. For example, a particular element may be designated as "xx" in one figure, by "1xx" in another figure, by "2xx" in another figure, and so on. It is noted that, according to common practice, the various features of the drawing are not to scale, and the dimensions of the various features are arbitrarily expanded or reduced for clarity.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGURE 1 is a plan view schematic diagram illustrating a semiconductor wafer 10, an exemplary wafer-level tack-free film 20, and the juxtaposition thereof, according to the invention. Semiconductor wafer 10 is typically circular and either 6 inches (15.24 cm), 8 inches (20.32 cm) or 12 inches (30.48 cm) in diameter. Wafer 10 has a front surface (not visible) on which electronic circuits and/or devices are formed and a back surface 12. Typically, a flat edge 14 is utilized for indexing the wafer 10 spatially for processing. Ultimately, wafer 10 is excised or separated into individual semiconductor die, often called "chips", each one containing one of the electronic circuits or devices previously formed on the front surface of wafer 10. In the excising process wafer 10 is attached to a tacky transfer adhesive film, is scored and broken or is sawed into individual die, and is removed from the transfer adhesive.

Tack-free adhesive film 20 is preferably a preform cut or fabricated in a size and shape to have a broad surface 22 that is substantially like the size and shape of

wafer 10. A "tack-free" adhesive typically feels dry to the touch and does not tend to adhere to whatever it comes into contact with. Tack-free film preform 20 is juxtaposed over back surface 12 of wafer 10 and is laminated thereto, as represented by dashed arrows A, preferably at a slightly elevated temperature, but not a high temperature. Optionally, tack-free film preform 20 may have a flat edge (indicated by dashed line 24) corresponding to the flat edge 14 of wafer 10. After tack-free film 20 is laminated to wafer 10, wafer 10 is excised into individual semiconductor circuits or die or chips 40 each having a portion of tack-free film 20 bonded thereto to provide tack-free adhesive preform 30 on the back surface of chip 40.

Thus, the tack-free adhesive film 20 is excised in a single operation as the individual chips 40 are excised from wafer 10, as represented by dashed arrows B, thereby eliminating a separate operation and the handling of individual die for the attachment of adhesive thereto. This beneficially saves processing time and expense. The surface opposite the front surface of chip 40 includes electrical contacts 42 that provide means for making electrical connections to the electronic circuit or device therein. Ultimately, chip 40 is attached to an electronic substrate or an electronic package by tack-free adhesive preform 30, and electrical connections are made to contacts 42 thereof, such as by bonding fine wires thereto in conventional manner.

Where a wafer-holding adhesive film is very thin, e.g., less than about 50 μm (about 2 mils), such wafer-holding adhesive film can tear upon removal of semiconductor wafer 10 from the dicing tape that is utilized to hold semiconductor wafer 10 during the dicing operation so that some of the wafer-holding adhesive film remains attached to semiconductor wafer 10 and some of the wafer-holding adhesive film transfers to and remains attached to the dicing tape, thereby leaving areas of wafer 10 lacking sufficient adhesive for properly attaching the excised semiconductor die 40 to a substrate, electronic package or the like. FIGURE 1A is a plan view schematic diagram illustrating a semiconductor wafer 10, a wafer-level tack-free film 20 including an intermediate or sacrificial layer (i.e. "interlayer") 26, and the juxtaposition thereof, according to the invention that overcomes the tearing so that sufficient adhesive remains on die 40 for properly attaching the excised semiconductor die 40 to a substrate, electronic package or the like.

Interlayer 26 is preferably adhered to the wafer-level adhesive layer 20 as described in relation to FIGURE 1 to provide a wafer-level tack-free film 20 with interlayer 26 that may be applied and utilized in like manner to wafer-level tack-free film 20 without interlayer 26. Preferably, interlayer 26 is an adhesive that is incompatible with and so does not permanently bond to the tack-free die-attach adhesive of film 20 so that it will more strongly adhere to or bond to the tacky dicing tape than to wafer-level film 20. Typically, a light tack of less than about 50 grams per inch of width (about 20 grams per centimeter of width) pull strength is provided for the interface with wafer-level film 20 and a higher strength adhesion to the wafer dicing tape. Also preferably, interlayer 26 will not have a layer of release material thereon so as to promote a stronger bond to the tacky dicing tape. Interlayer 26 should be compatible with the lamination temperature and pressure utilized in attaching tack-free film 20 to semiconductor wafer 10, e.g., typically a temperature in the range of 80-150°C and a pressure in the range of about 5-20 psi (about 0.35-1.4 kg/cm^2), without causing the tacky dicing tape adhesive to transfer to the die-attach adhesive film 20 on die 40 after dicing and removal from the tacky dicing tape. To the extent that interlayer 26 leaves adhesive residue on die-attach film 20 (illustrated as phantom layer 26' on preform 30), such adhesive residue preferably changes the surface energy of the die-attach film 20 by less than 50%.

Preferable wafer mounting interlayer materials include types WMF 50, WMF 100, and WMF-HT 100 sheet or film adhesive tapes available from AI Technology, Inc., located in Princeton, New Jersey, which are not coated with a release material, however, conventional light-tack dicing tapes having a release coating, such as types PN1009R, PN1010R, and PN1011R available from Ultron Systems, Inc. located in California and G-11, G-12, G-16, G-26, G-36 and G-65 available from Lintec Corporation located in Japan, could be utilized.

Thus, semiconductor wafer 10 is attached to wafer-level tack-free film 20 which is attached to a conventional wafer dicing tape by sacrificial or interlayer 26. The cutting of semiconductor wafer 10 in a dicing operation should cut through wafer-level film 20 and may cut partly or completely through interlayer 26. When the excised die 40 are picked up, interlayer 26 will adhere to the tacky dicing tape and

wafer-level film 20 will adhere as preform 30 to the die 40 without damage to wafer-level film 20 which remains attached to die 40. It is noted that the relatively weak adhesion of interlayer 26 to wafer-level tack-free film 20 will help die 40 to easily release from the tacky dicing tape. For example, this is particularly so where the adhesive of interlayer 26 is incompatible with that of wafer-level film 20 as is the case with interlayer film types WMF 50 and WMF 100 for which surface energy analysis indicates there is no transfer of the tacky dicing tape adhesive to wafer-level tack-free film 20. Where the tacky dicing tape is a UV release type tape, it is preferred that the tape not be exposed to UV radiation so that interlayer 26 will remain with the UV tacky dicing tape.

Tack-free film 20 may be of electrically conductive adhesive or of insulating dielectric adhesive, and/or may be filled with thermally conductive particles so as to be more thermally conductive, as may be interlayer 26. Such adhesive may be molecularly flexible, i.e. it has a modulus of elasticity that is about 35000 kg/cm^2 (about 500,000 psi) or less and withstand an elongation of 30% or more without failure, at least over a substantial portion of the temperature range to which it is expected to experience. Preferably, tack-free film 20 and interlayer 26, if any, is of such molecularly flexible adhesive where an individual semiconductor die is large, e.g., has an edge dimension of 20 mm or larger. For larger die, a molecularly flexible adhesive having a modulus of elasticity less than 7000 kg/cm^2 (about 100,000 psi) is preferred. Tack-free film 20 and interlayer 26, if any, also desirably has a sufficiently high bond strength and low enough modulus of elasticity to provide a die attachment bond that withstands the stresses caused by the process of attaching bond wires to the contacts on the front side of the semiconductor die, e.g., temperatures of about 150-250°C. In addition, tack-free film 20 and interlayer 26, if any, is preferably storable for extended periods, e.g., at least 12 months, under ambient conditions, including time both before and after the tack-free film is laminated or tacked to the semiconductor wafer.

Alternatively, tack-free film 20 may be a preform 20' formed as a pattern of preforms 30 on a release liner or release substrate 32, as illustrated in the plan view schematic diagram of FIGURE 2. Preferably, release substrate 32 is of size and shape

substantially like that of wafer 10, including a flat edge 34 which can be registered with edge 14 of wafer 10 to, perhaps with other fiducial or registration marks or indicia, properly position preform 20' with respect to wafer 10. In particular, the pattern of preforms 30 corresponds to the pattern of electronic circuits and/or electronic devices formed on the front surface of wafer 10, each preform 30 being of like size and shape to the electronic circuit or device to which it is to be attached. Spaces or "streets" 36 separating preforms 30 are in the locations where wafer 10 will be cut or separated into individual die.

Preform 20' is laminated to the back surface 12 of wafer 10 with each preform 30 being laminated to the back of one of the semiconductor circuits or devices thereon, to be excised therewith when wafer 10 is excised, as described above. Alternatively, preform 20' could be laminated to the front surface of wafer 10 if the spacing 36 between preforms 30 is sufficiently wide so that preforms 30 do not overlie electrical contacts 42 on the front surface of the individual circuits 40 of wafer 10. Preforms 30 are of the same electrically conductive or insulating, and/or thermally conductive, materials as described above in relation to tack free film 20, and may or may not include a sacrificial layer or interlayer 26 as described above. Because preforms 30 are securely attached to wafer 10 as a result of being laminated thereto, release liner 36 is easily removed after preform 20' is laminated to wafer 10 and prior to the excising of wafer 10 into individual die 40.

In accordance with the invention, a dry, tack-free film of adhesive provides the die-attachment adhesive for semiconductor die or other electronic devices. Typically, the tack-free adhesive film is a thin film having a thickness in the range of about 0.25 - 1.5 mm (about 1 - 6 mils) and may be a thermoplastic or thermosetting adhesive, or a blend or mixture thereof, or a laminate thereof, or a hybrid thereof. A laminate includes alternating layers of thermoplastic and thermosetting adhesive film that are laminated together. A hybrid includes any combination of two or more of a blend, a mono-layer film and a laminate. The adhesion of the tack-free adhesive to the semiconductor wafer should be good enough that the adhesive material and its adhesion to each individual die is substantially unaffected by the dicing and cleaning process that the wafer will be subjected to. For example, the adhesion of the uncured

thermosetting adhesive to the wafer due to its melt flow tacking properties must be high enough so that the adhesive stays attached to the die when the die is removed from the tacky pressure sensitive film of dicing tape conventionally utilized in the process of excising the individual die from the wafer. They also must be unaffected by exposure to ultraviolet (UV) light which is used in curing some conventional dicing tape adhesive films. In addition, the tack-free adhesive and the bond thereof to the semiconductor wafer and die must be able to withstand the washing and other cleaning procedures, and the cleaning and degreasing agents and other chemicals utilized therein, to which the wafer and die are subjected.

For the wafer-size adhesive film to have the preferred tacking and curing properties, they should also have significant strength so as to be handled as a thin film of dried or B-staged adhesive. Typical conventional films of B-staged rigid epoxy have significant body, but are too brittle to be handled and so must be carried with a carrier for support, such as a polyimide film or an epoxy glass fabric. While such supported epoxy films may be used, they typically interfere with the dicing of the semiconductor wafer and do not easily separate with precise excising on the back of the wafer into individual preforms. Other adhesive films, such as flexible film adhesive types TK7755 and TC8750, or ESP7455 and ESP8450, available from Al Technology located in Princeton, New Jersey, have sufficient body and flexibility for satisfactory handling and so can be utilized as a wafer-level preform, however, they do require significant pressure to be maintained for tacking so that part movement does not occur and voids are not created, and so are less advantageous.

Suitable adhesive films are made with a suitable combination of thermoplastic and thermosetting resins that are sufficiently molecularly compatible to form a suitable solution and, when dried to remove solvents, to form a suitable film. Typically, a solid epoxy resin is employed as one component of the combination so as to produce a film that is dry to the touch and tack-free. The removal of solvents in forming a film must be performed at a low temperature so that excessive curing of the epoxy component does not occur, which would impede the desired melt-flow property of the adhesive film. Likewise, curing agents and catalysts that would cause excessive curing before the film adhesive is utilized should be avoided.

Suitable thermoplastics include acrylics and polyesters and suitable epoxy resins include Quartex 2410 solid epoxy resin available from Shell Chemical Company located in Texas, U.S.A., and similar resins. Suitable polar solvents include n-methyl pyrrolidinone (NMP) or tetrahyfrofuran may be utilized as a compatible solvents. Curing agents or catalysts such as dicyanamide or other slow reactivity catalysts that are commonly utilized for epoxy laminates and molding compounds may also be utilized.

Suitable thermosetting film adhesives typically cure rapidly at a temperature of 150°C or above, and will melt and be flowable for tacking at a temperature in the range of 60 - 120°C or even to 150°C so as to be adhesively laminated onto the semiconductor wafer with little or no curing, at least no significant curing, while having the characteristic of being dry and substantially tack-free at normal handling and storage temperatures. Such tack-free adhesive film is laminated or otherwise attached onto the back surface of a wafer at a temperature of 80 - 120°C with sufficient pressure (about 0.2 - 7 kg/cm^2 or about 3 - 100 psi) for a controlled short period of time of less than 10 minutes, and preferably much less than 10 minutes. If necessary, multiple passes of the laminating apparatus may be used to ensure intimate adhesive without trapped air or voids as long as the total time the thermosetting adhesive is at an elevated temperature is sufficiently short so that no significant curing occurs. Once the lamination is completed and the wafer and film cool to ambient temperature, the adhesive will again be tack-free and the wafer with die-attach adhesive thereon is ready for wafer dicing.

Suitable thermoplastic adhesives typically are melt-flowable at a temperature in the range of 100 - 300°C. The melting temperature of the suitable thermoplastic adhesives should be well defined and repeatable so that their thermal stability is adequate for at least several passes through the laminating apparatus at a suitable temperature for lamination, e.g., at a temperature as high as 300°C for those varieties of film adhesive having a high melting temperature. In general, the time for which a thermoplastic adhesive is exposed to melting temperature during the lamination process is not critical. The wafer with tack-free adhesive film laminated thereto is then ready for dicing. The temperature must be raised high enough for a time

sufficient to produce adequate adhesive flow at the pressure utilized to ensure intimate contact and bonding of the tack-free adhesive film to the semiconductor wafer, thereby to allow removal of the individual die and attached tack-free adhesive film from the tacky pressure sensitive dicing tape.

Suitable dry, tack-free adhesive films include the following types listed in order of ascending lamination temperature, all of which are available from AI Technology, Inc. located in Princeton Junction, New Jersey , such as in standard thicknesses of 3 mils and 6 mils (about 0.075 and 0.15 mm).

Laminate at 80 -120°C at about 0.35 - 1.4 kg/cm^2 (about 5 - 20 psi) for a few seconds until a fillet of melted adhesive is observed: types ESP8550 and ESP8680 thermosetting electrically conductive epoxy film and types ESP7555 and ESP7675 thermosetting dielectric epoxy film, that, after tacking or lamination, cure without pressure at 80°C for 8 hours. Type ESP7555 can be tacked or laminated at 80°C at less than 0.07 kg/cm^2 (about 1 psi) and then cured without pressure at 80°C for 2 hours. Each material may be cured at a higher temperature for a shorter time.

Laminate at 120 - 150°C at about 0.35 - 1.4 kg/cm^2 (about 5 - 20 psi) for a few seconds until a fillet of melted adhesive is observed: type CP7135-E thermoplastic electrically-insulating thermally-conductive film and types CP7138-E thermoplastic epoxidated film, that, after tacking or lamination, need no cure. Type CP7135-E can be tacked or laminated at 135°C at nominal pressure in 0.5 second and type TP7090 can be tacked or laminated at >120°C at nominal pressure in less than 0.5 second.

Laminate at 175 - 250°C at about 0.35 - 0.7 kg/cm^2 (about 5 - 10 psi) for 0.5 - 5 seconds until a fillet of melted adhesive is observed: type TP8150 thermoplastic electrically and thermally conductive adhesive film and type TP7150 thermoplastic dielectric adhesive film, that, after tacking or lamination, need no cure.

It is noted that while these adhesives are characterized as "thermoplastic" or "thermosetting" adhesives, they are actually blends or mixtures in which the properties of the one of thermoplastic or thermosetting type adhesive predominates.

In such adhesive that is a "thermoplastic" adhesive, for example, thermosetting resin may be present in minor amount, typically less than about 20% by weight, to give the adhesive desirable thermoplastic properties in its dried or B-staged sheet or film form, and thermoset properties in that it has a cured state of the polymer network. In such adhesive that is a "thermosetting" adhesive, for example, thermoplastic resin may be present in an amount up to about 80% by weight, but typically less, so that the adhesive has desirable thermosetting curing properties and yet is melt-flowable in its dried or B-staged sheet or film form. Such thermoplastic and thermosetting adhesives may be utilized in paste or liquid form, or in dried or B-staged sheet or film form.

One benefit of such adhesives is that of having suitable stability before the thermosetting adhesive component is cured. This provides the ability to maintain the die position and bond-line integrity at the interface between die-attach adhesive and die as well as at the interface between die-attach adhesive and a substrate or package, in particular during completion of curing without pressure.

This property is extremely important for certain applications, for example, for the stacking of two or more die and for optoelectronic devices where relative position of the die and substrate must be accurately maintained for high productivity. The ability of the die-attach adhesive to maintain the die in the position in which it is placed on a substrate or within a package to within about 25 micrometers (25 microns or about 1 mil) during the curing of the adhesive without any applied pressure or other mechanical stabilization is very desirable. In particular, such stability may be critical where die attached in accordance with the invention are attached by high volume in-line processing, such as by high-speed pick-and-place equipment. Lacking such characteristics as being able to tack (i.e. to melt and induce flow for forming an intimate substantially void-free bond line) at a temperature of about 175°C or less when placed under a pressure of less than about 1 kg/cm^2 (about 15 psi) for a few seconds or less; and subsequently to cure while retaining its shape and position without any applied pressure, even the adhesive is still in its "wet" or uncured state; renders achieving a low cost in-line high-speed die attach process extremely difficult, if not impossible. The ability of at least certain embodiments of the invention to achieve such result renders it attractive and cost effective.

Besides having sufficient stability to enable pre-lamination of wafer-sized thin sheets of dried or B-staged adhesive onto a semiconductor wafer or other substrate at low temperatures before the subsequent tack-and-cure process by which the semiconductor die is attached to a substrate or package, these dry, tack-free high flow adhesive films also have adequate integrity to be excised into individual adhesive preforms, even apart from a semiconductor wafer. Thus, these excised preforms can be handled in like manner to a component that is placed on a substrate or semiconductor die or other electronic component by conventional pick-and-place equipment, including, for example, placement between a die and a substrate or being tacked onto a die or substrate individually, if desired. The same or similar tack-and-cure process can then be utilized to finish the attaching of individual die into packages, or onto substrates or other assemblies, advantageously in an in-line production process. In addition, the suitable adhesive films described herein are storable for extended periods, both before and after being laminated to the semiconductor wafer, typically 12 months or more at ambient temperature and humidity.

In some cases, a tack-free film 120 of an anisotropic electrically conductive adhesive may be employed. FIGURES 3A and 3B are plan view and side cross-sectional view schematic diagrams, respectively, of an alternative exemplary embodiment of an anisotropic electrically conductive wafer-level tack-free film 120 according to the invention. Anisotropic conductive adhesives include a dielectric adhesive 122 in which are dispersed a multiplicity of electrically conductive particles 124, preferably elongated particles 124 that are relatively uniform in size, e.g., within about 10% of each other, and that tend to be oriented in a transverse direction between the two broad surfaces 126, 128 of film 120. The density of particles 124 is such that there is normally insignificant electrical conductivity in a direction parallel to broad surfaces 126, 128, but there is good electrical conductivity in a direction between broad surfaces 126, 128. It is noted that particles 124 are not to scale with the wafer-level size of film 120, but are enlarged for clarity.

Because of the selective and directional conductivity of film 120, it is applied such as by lamination onto the front surface of a wafer 10 and wafer 10 is diced into

individual die 40, in like manner to that described above. Before adhesive film 120 is applied to wafer 10, however, the contact pads of wafer 10 and of the individual die 40 thereof should be covered with a layer of nickel-gold, gold, silver, platinum, palladium, other precious metal or other similar metallization to prevent oxidation. The thickness of the finishing layer of gold or other precious metal combined with any underlying layer such as a nickel layer, must be such that the top of the contact 42 will be exposed and extend above the surface of the wafer 10, including any passivating or other dielectric layer on the wafer 10.

FIGURE 4 is a side cross-sectional schematic diagram of an exemplary electronic assembly 100 including attachment of an electronic device 40 to an electronic substrate 110 by employing the alternative exemplary wafer-level tack-free film 120 of FIGURES 3A and 3B. Electrical contacts 42 of device 40 project above the respective surfaces thereof to make electrical contact with those electrically conductive particles 124 of anisotropic conductive film 120 proximate thereto when film 120 is laminated to wafer 10. Substrate 110 has a respective pattern of electrical contacts 112 thereon that corresponds to the pattern of contacts 42 on device 40 are adapted to be interconnected therewith when device 40 is placed against substrate 40 in a flip-chip mounting manner. Electrical contacts 112 of substrate 110 project above the surface thereof to make electrical contact with those electrically conductive particles 124 of anisotropic conductive film 120 proximate thereto when electronic device 40 with anisotropic conductive film 120 attached thereto is pressed against substrate 110, preferably at an elevated temperature sufficient to melt flow the adhesive 122 of film 120 to at least tack device 40 thereto. If anisotropic conductive film 122 is a thermosetting adhesive, the assembly 40, 120, 110 is heated for a time sufficient to cure adhesive 122, as described above.

The anisotropic electrically conductive adhesive have similar tacking and curing properties to the adhesives described above. Suitable dry, tack-free anisotropic conductive adhesives include types ZTP8090, ZTP8150, ZTP8090-FP and ZTP8150-FP thermoplastic adhesive films and types ZEF8450, ZEF8450-FP, ZEF8410 and ZEF8410-FP thermosetting epoxy-based adhesive films, all of which are available from AI Technology, Inc., such as in standard thicknesses of 2 and 6 mils (about 0.05

and 0.15 mm).

Adhesive films having like four-digit numerical designations to those identified above in relation to FIGURES 1, 2A and 2B have similar lamination, tacking, bonding and/or curing properties thereto. In this regard, for example, type ZTP8090 anisotropic electrically conductive film is similar to type TP8090 thermoplastic electrically conductive adhesive film which melt flows for bonding at a temperature above 120°C in 1 - 5 seconds when under at least 10 psi (about 0.7 kg/cm^2) pressure and at above 150°C in less than 1 second with less than 5 psi (about 0.35 kg/cm^2) pressure. It is noted that types ZEF8450, ZEF8450-FP, ZEF8410 and ZEF8410-FP adhesive films exhibit desirable high melt flow as is desirable for the tack-and-cure process described herein.

FIGURE 5 is a side cross-sectional schematic diagram of an exemplary electronic assembly 200 including attachment of one or more electronic devices 40 to an electronic substrate 210 employing the exemplary embodiment of a wafer-level tack-free film 20 of FIGURE 1 or 2. Substrate 210 is a conventional electronic substrate such as a ceramic substrate or a printed circuit wiring board, and has a plurality of contacts 212 thereon in a pattern to make contact with the electronic components to be mounted thereto. Substrate 210 typically includes a pattern of electrical conductors to interconnect contacts 212 and the electronic components connected thereto into a desired electronic circuit. Each electronic device 40 is, for example, a semiconductor die 40 excised from a semiconductor wafer 10 with a preform 30 of die-attach adhesive attached thereto, which die-attach adhesive 30 was applied to wafer 10 as a dry, tack-free film 20 prior to individual die 40 being excised therefrom. Beginning at the left in FIGURE 5, semiconductor die 40 is attached to substrate 210 by die attach adhesive 30 and the generally peripherally located contacts 42 thereof are electrically connected to appropriate respective ones of contacts 212 of substrate 210 by fine wire bonds 216.

Nearer the center of FIGURE 5, another semiconductor die 40 is similarly attached and connected to substrate 210 and has attached to a central region of the top surface thereof not covering its contacts 42 which are located around its periphery, yet another semiconductor die 40a. Die 40a is attached to die 40 by die-attach adhesive

preform 30a which was applied to die 40a at wafer level in similar manner to that previously described. Bond wires 217 connect ones of contacts 42 of die 40a to ones of contacts 42 of die 40, or alternatively directly to contacts 212 of substrate 210. Additional die could be stacked in similar manner, as desired, except that the number of die is limited by the fact that each die must be smaller than the one below, i.e. the one nearer substrate 210. Such assemblies of stacked chips are facilitated by the well defined area and flow properties of the die attach adhesive.

At the right in FIGURE 5, three semiconductor die 40', 40'a, 40'b are stacked and attached to each other and to substrate 210 by respective die-attach adhesive 30, 30a, 30b which was applied thereto at wafer level in similar manner to that previously described. Die 40', 40'a, 40'b have electrical contacts at the periphery thereof that can be connected to at the edges thereof and so vertical conductors 218, 219 provide electrical connections between various ones of the edge contacts of die 40', 40'a, 40'b and ones of contacts 212 of substrate 210.

By employing dry, tack-free adhesive films having properties like the suitable characteristics set forth above, tack-free adhesive films have been found to be easily laminated onto semiconductor wafers quickly and with repeatable results. Thus, productivity and repeatability are dramatically improved by employing the invention as compared to prior art processes employing tacky films. The invention advantageously can allow meaningful improvement in production usage and reduction of production cost.

The method according to the present invention is now described in detail, for example, for making the embodiments described above. This method is sometimes referred to herein as the "tack-and-cure" method because the wafer level die-attach adhesive preform is first "tacked" to the semiconductor wafer, and individual semiconductor die excised therefrom with die-attach adhesive attached are then "tacked" to an electronic circuit board, package or other substrate, followed by the curing of the die-attach adhesive thereafter. Curing of the die-attach adhesive is done without the addition of or maintenance of pressure to hold the die against the circuit board, package or other substrate.

The melt-tacking process according to the invention preferably utilizes a

laminator having a pair of heat-controlled rollers or zones that are heated to a temperature sufficient to raise the adhesive being laminated to the semiconductor wafer to reach the desired temperature for tacking. Typically, heated lamination rollers that are suitable for teaching the melt-bonding (melt-flow) temperatures of a variety of thermoplastic die-attach adhesive films and of thermosetting epoxy die-attach adhesive films are desirable. Epoxy adhesive films also have been successfully tacked onto semiconductor wafers using a standard office-type (PE/PP) plastic film laminator, such as model HD1200 available from U.S.I. located in Madison Connecticut.

Specifically, the preferred lamination process comprises preheating the laminator to the required temperature for tacking the die-attach adhesive. It is to be noted that the transfer of heat from the laminator to the die-attach adhesive film takes a certain amount of time, and that the lamination time depends on the speed of laminator, i.e. the roller rotation rate or feed rate as well as its temperature. It is also desirable that a protective buffer liner be utilized to help prevent the laminator producing an excessive stress concentration that could either result in uneven lamination or damage to the wafer. Preferably, the protective buffer is utilized with a sheet of release material to which the die-attach adhesive will not adhere, or is itself a release material. A Teflon® cloth of about 0.05 - 0.30 mm (about 2 - 6 mils) thickness has been found suitable for many laminations, and a soft non-silicone rubber pad is also suitable.

Where the die-attaeh adhesive film or die-attach adhesive preform is obtained from AI Technology, it is preferred that the release liner supplied therewith be utilized. A suitable thermal transfer protective buffer sheet type TP7178 may be utilized against the wafer side to facilitate the transfer of heat to the wafer. The type TP7180 buffer sheet and other similar low surface energy films may also be utilized as a release liner sheet or buffer sheet between the die-attach adhesive film tacked to the semiconductor wafer and the conventional tacky wafer dicing tape utilized in dicing the wafer. The low surface energy characteristic of such buffer sheets is such that the adhesion of the die-attach adhesive to the semiconductor wafer is greater than is the adhesion of the buffer sheet to the die-attach adhesive, so that the die-attach

adhesive remains tacked to the semiconductor wafer or die when the buffer sheet and tacky dicing tape is removed. Thus, the buffer or release material preferentially adheres to the tacky dicing tape and is removed therewith.

The protective buffer/wafer/adhesive film/release liner"sandwich" comprising the semiconductor wafer adjacent to the die-attach adhesive preform, with the release liner over the adhesive preform, is passed trough the heated laminator rollers to melt-flow the die-attach adhesive tacking it to the wafer. It is sometimes preferred to pass the once-laminated sandwich through the heated laminator rollers at least once again to ensure that all the edges and/or corners reach the melt-tacking temperature.

Other film lamination methods may be employed in the method according to the invention. For example, conventional lamination presses and vacuum lamination techniques may be utilized, including those utilizing externally applied pressure as well as the vacuum bag techniques that are commonly used to bond a temporary adhesive film on wafer. In fact, any laminating method that can provide sufficient temperature and pressure to melt flow and bond the die-attach adhesive while maintaining the temperature, but not significantly cure the adhesive (i.e. that maintains temperature and heating time below the temperature-time profile for curing the adhesive) may be utilized.

A suitable laminator for the wafer-level tack-free adhesive preform described herein includes a pair of cushioned rollers that can be heated in a controlled manner to a desired temperature in the range of about 60 - 200°C, for example, with a tolerance of ±2°C. Cushioned rollers are most desirable so as to maintain a substantially constant value of pressure on the wafer and tack-free adhesive preform being laminated thereto, and such rollers are preferably spring-loaded and resilient (e.g., have a rubberized surface) so as to expel entrapped air between the wafer and the adhesive preform laminated thereto. Laminator temperature is monitored and controlled, such as by a K-type thermocouple, and lamination time is controlled by controlling the feed rate of the laminator, such as to a typical rate of about 30.5 cm (about 12 inches) per minute. Preferably, the laminator is compatible with operation in a clean room environment, and with the non-stick wafer holders described below.

The efficiency and productivity of wafer-level lamination of tack-free

high-flow B-staged epoxy film die-attach adhesive preforms is evident from the following progression for a single in-line lamination processing station. For semiconductor wafers of 12-inch (30.48 cm) diameter and a laminator feed rate of 12 inches (30.5 cm) per minute, one wafer is laminated per minute. This single-station, single shift operation thus nominally produces 60 laminated wafers per hour, or 480 laminated wafers per eight-hour day, or 2880 laminated wafers per six-day week, or 149,760, i.e. almost 150,000, laminated wafers per year. For 6-inch (15.24 cm) diameter wafers and the same feed rate, such single in-line lamination station can produce almost 300,000 laminated wafers per year.

Preferred thermosetting tack-free die-attach adhesive materials for use in the "tack-and-cure" method include epoxy films type ESP8680, ESP8550, ESP7675, ESP7555 and high melt-flow epoxy films types ESP8680-HF, ESP8350-HF, ESP7676-HF, ESP7675-HF, ESP7355-HF, which are all thermosetting adhesive films available from AI Technology. These adhesives melt and flow suitably for lamination at a temperature in the range of about 80 - 100°C within a typical lamination time of a few seconds. Even at a temperature below 100°C, the time should be kept as short as possible, preferably only a few seconds, and should be kept below 10 minutes so as to avoid excessive pre-curing prior to attaching the die to a substrate or package.

Preferred thermoplastic tack-free die-attach adhesive materials for use in the method include adhesive films of the following types (having melt-bonding temperatures as given in parentheses after each type number): TP7260 (280 - 300°C), TP8260 (280 - 300°C), TP8150 (210 - 230°C), and TP7150 (210 - 230°C), all of which are thermoplastic film adhesives available from AI Technology. The adhesive must reach the melt-bonding temperature at which the onset of melting and flowing of the adhesive commences and at which bonding occurs with the prescribed pressure applied. Tacking and bonding are essentially instantaneous once the melt-bonding temperature is reached, and the adhesive is allowed to cool thereafter.

All of the preceding adhesives are self-supporting without the need for any fiber-glass mesh or other support. Suitable support for holding and handling the semiconductor wafer is desirable and is described below.

With the use of an adhesive film specifically engineered for high flow, such as

types ESP8680-HF, ESP7675-HF, ESP7355-HF, and ESP7350-HF, it is not necessary to maintain pressure during curing. Such adhesive films can be induced to melt and flow for tacking and will maintain its tacked position and bond without the maintenance of pressure during the completion of the curing process. Thus, the tool utilized for applying pressure during tacking (bonding) can be released after a few seconds during the melt and flow process, thereby facilitating the utilization of such films in an in-line process, e.g., a continuous processing line as contrasted to a batch processing operation. As described above, the time required for inducing melt-flow of the adhesive depends on both pressure and temperature, and thus the liquidous nature of the adhesive. Such rapid tacking and no-pressure curing properties are important where it is desired to utilize film adhesives in an in-line bonding process suitable for large-volume die-attaching applications.

Desirably, adhesive tacking as described earlier can be done at a laminator temperature in the range of 60 - 200°C, and more typically 60 - 150°C, with a lamination pressure of about 0.2 kg/cm^2 (about 3 psi) or more for a time as short as a few seconds and preferably less than one second. Curing the tacked adhesive is then performed at temperatures the same or different from the tacking temperature, and without the pressure-applying fixtures and/or tooling that is required for tacking.

FIGURE 6A is a plan view schematic diagram of an exemplary holder 300 for semiconductor wafer 10 and FIGURE 6B is a side cross-sectional schematic diagram of the holder 300 of FIGURE 6A with a wafer 10 therein. Wafer holder 300, which is suitable for use in the method described above, is preferably rectangular having a length L between about 18 and 33 cm (about 7 - 13 inches) and a width W between about 20 - 36 cm (about 8 - 14 inches) as is suitable for the particular diameter of wafer 10 (e.g., conventional wafer diameters referred to as 4", 5", 6", 8", 10", and 12" wafers (about 10.16, 12.7, 15.24, 20.32 25.4 and 30.48 cm wafers) that holder 300 is to hold. Wafer holder 300 has a generally circular recess 310 therein for receiving wafer 10, and recess 310 may include a flat edge 312 for engaging the flat edge 12 of wafer 10 thereby to locate and orient wafer 10 in a predetermined position in holder 300. The depth D_R of recess 310 is less than the thickness of wafer 10 so that wafer 10 extends above holder 300 for receiving heat and pressure for tacking die-attach

adhesive preform 20 thereto, such as pressure applied by a heated press or by a pair of heated rollers. As a result, peripheral flange 330 advantageously does not come into contact with the heated press or rollers, thereby facilitating the heating of wafer 10 and shortening the time required to heat die-attach wafer preform 20 and wafer 10 to a suitable temperature for tacking die-attach adhesive preform 20 thereto.

Non-stick wafer holder 300 may also optionally include a shoulder 320 for facilitating the grasping of wafer 10 by its edge, as may be convenient for removing wafer 10 from holder 300. Typical wafers are about 0.25 - 0.5 mm (about 10 - 20 mils) thick, and the height of shoulder 320 is typically about one half of the wafer thickness, and should be about 0.15 - 0.20 mm (about 6 - 8 mils) to retain wafer 10 radially. Wafer holder 300 is preferably of a material to which die-attach adhesive 20 will not adhere, such as PTFE or of stamped or formed metal such as stainless steel or aluminum coated with a non-stick material such as PTFE or silicone, and the thickness T_M of the material is typically about 0.20 - 0.30 mm (about 8 - 12 mils). Also typically, the overall thickness T_H of holder 300 is about 0.25 - 0.50 mm (about 10 - 20 mils) where the thickness of wafer 10 is about 0.20 - 0.45 mm (about 8 - 18 mils).

In utilizing wafer holder 300, wafer 10 is placed in recess 310 and tack-free wafer level die-attach adhesive film preform 20 is placed on wafer 10. Typically, die-attach adhesive film preform 20 is about 0.075 - 0.15 mm (about 3 - 6 mils) thick and is smaller in diameter than wafer 10 by about 0.025 - 0.075 mm (about 1 - 3 mils). The straight edges of holder 300 are particularly suitable for being fed through heated rollers for laminating die-attach adhesive preform 20 to wafer 10, the straight edge thereof being of like shape to the contact line between cylindrical laminating rollers. Preferably, a release substrate or release liner 336 is placed over die-attach adhesive preform 20 so that it does not adhere to the laminating rollers or press.

Holder 300 also advantageously may be a section of a belt or conveyor, as represented by the dashed lines 320 extending from the sides of holder 300 along the direction of lamination indicated by arrow 322. Such belt or conveyor includes a number of recesses 310 along its length for holding a number of wafers 10 and for moving such wafers 10 through a pair of laminating rollers in an in-line continuous

process. Such apparatus may also include die-attach adhesive preform 20 and/or release liner 336 in strip or ribbon form, or on reels, for automatic feed and placement onto wafers 20, and may also include pick-and-place equipment for placing wafers 10 into holders 300 and/or for removing them therefrom after die-attach adhesive preform 20 is laminated thereto.

FIGURE 7 is a plan view schematic diagram of an alternative embodiment of an exemplary wafer holder 400 having a generally circular recess or opening 410 into which wafer 10 is placed, as for processing in accordance with the invention. Wafer holder 400 has a generally circular recess 410 therein for receiving wafer 10, and recess 410 may include a flat edge 412 for engaging the flat edge 12 of wafer 10 thereby to locate and orient wafer 10 in a predetermined position in holder 400. The dimensions of wafer holder 400 and the recess 410 therein, and of the materials of which it is made, are like those described in relation to wafer holder 300. Wafer holder 400 is preferably of a material to which die-attach adhesive 20 will not adhere, such as PTFE or of metal such as stainless steel or aluminum coated with a non-stick material such as PTFE or silicone.

While wafer holder 400 is suitable for use with a heated lamination press, its generally circular shape can present difficulties in feeding holder 400 with wafer 10 therein through laminating rollers. FIGURE 8 is a side view schematic diagram of a wafer carrier 450 having therein a wafer 10 in the exemplary holder 300 or 400 of FIGURE 6A or 7, respectively, and is particularly useful for feeding wafers 10 in non-rectangular holder 400 through a pair of laminating rollers. Wafer carrier 450 is preferably of a material to which die-attach adhesive 20 will not adhere, such as PTFE or of metal such as stainless steel or aluminum coated with a non-stick material such as PTFE or silicone. Carrier 450 is preferably a rectangular sheet of PTFE having a thickness of about 0.075 mm (about 3 mils) that is folded along line 456 to form upper and lower covers 452 and 454 joined together at hinge line 456. A wafer holder 300 or 400 with a wafer 10 therein, and having a die-attach adhesive preform 20 placed on wafer 10, is placed between covers 452, 454 of carrier 450, and is then placed in a heated lamination press or is fed through heated lamination rollers to tack laminate preform 20 to wafer 10. Carrier 450 may also be used as a protective storage

device for storing wafers 10 with die-attach adhesive preform 20 laminated thereto.

While the present invention has been described in terms of the foregoing exemplary embodiments, variations within the scope and spirit of the present invention as defined by the claims following will be apparent to those skilled in the art. For example, the tack-free film may be of like size as or larger or smaller than the wafer to which it is tacked, and may be laminated to the wafer using rollers, a press or any other suitable method, whether using an in-line process, a batch process, or one at a time. Although it is not necessary that the preferred tack-free adhesive films be clamped or maintained under pressure after they are tacked to the wafer, or after a die having the tack-free die attach adhesive film tacked thereon is tacked to a package or substrate, one may do so if one so desires.

While examples of tacking the tack-free die-attach adhesive by applying certain exemplary levels of heat and pressure thereto are described, any combination of heat and pressure effective to melt flow the tack-free die-attach adhesive film without significantly curing the thermosetting adhesive resin may be employed. The thermosetting adhesive is considered to not have significantly cured if it remains able to melt-flow and tack onto a substrate with less than about 1 kg/cm^2 (about 15 psi) of applied pressure.

WHAT IS CLAIMED IS:

1. A method for making a semiconductor die having a tack-free die-attach adhesive preform thereon comprising:

providing a film of tack-free die-attach adhesive;

placing the film of tack-free die-attach adhesive against a semiconductor wafer;

heating at least the tack-free die-attach adhesive film and tacking the tack-free die-attach adhesive film to the semiconductor wafer; and

excising the semiconductor wafer and the tack-free die-attach adhesive preform tacked thereto into individual semiconductor die each having a portion of the tack-free die-attach adhesive film tacked thereto.

2. The method of claim 1 wherein the tack-free die-attach adhesive includes at least one of a thermoplastic adhesive, a thermosetting adhesive, and a blend, mixture, combination, laminate, and hybrid thereof.

3. The method of claim 2 wherein the tack-free die-attach adhesive is predominantly thermoplastic adhesive having a melt-flow temperature in the range of 100 - 300°C.

4. The method of claim 2 wherein the tack-free die-attach adhesive is predominantly thermosetting adhesive having a melt-flow temperature in the range of 60 - 150°C.

5. The method of claim 2 wherein the tack-free die-attach adhesive is molecularly flexible.

6. The method of claim 1 wherein the film of tack-free die-attach adhesive is self supporting without a supporting film or mesh.

7. The method of claim 1 wherein said heating and tacking includes laminating the tack-free die-attach adhesive film to the semiconductor wafer.

8. The method of claim 7 wherein said laminating includes pressing the semiconductor wafer and the film of tack-free die-attach adhesive film placed thereagainst using one of a heated lamination press and a pair of heated lamination rollers.

9. The method of claim 7 further comprising placing the semiconductor wafer in a non-stick wafer holder having a recess shaped for holding the semiconductor wafer before said placing the film of tack-free die-attach adhesive against the semiconductor wafer.

10. The method of claim 9 further comprising placing a sheet of release material on the film of tack-free die-attach adhesive.

11. The method of claim 1 further comprising heating at least the portion of the tack-free die-attach adhesive film tacked to a first one of the semiconductor die and placing the tack-free die-attach adhesive tacked thereto against an electronic substrate to tack the first semiconductor die thereto.

12. The method of claim 11 further comprising pressing the semiconductor die against the electronic substrate while curing the tack-free die-attach adhesive.

13. The method of claim 11 further comprising curing the tack-free die-attach adhesive without pressing the semiconductor die against the electronic substrate.

14. The method of claim 11 further comprising heating at least the portion of the tack-free die-attach adhesive film tacked to a second one of the semiconductor die and placing the tack-free die-attach adhesive tacked thereto against the first semiconductor die to tack the first semiconductor die thereto.

15. The method of claim 1 wherein said providing a film of tack-free die-attach adhesive includes providing a tack-free die-attach adhesive preform including a pattern of individual tack-free die-attach adhesive preforms on a release liner, wherein the pattern of individual tack-free die-attach adhesive preforms corresponds to a pattern of individual electronic circuits of the semiconductor wafer and has spaces between the individual tack-free die-attach adhesive preforms corresponding to excising spaces of the semiconductor wafer.

16. The method of claim 1 wherein said tack-free die-attach adhesive is at least one of insulating, electrically conductive, anisotropic electrically conductive and thermally conductive.

17. The method of claim 1 wherein said excising the semiconductor wafer includes placing a buffer sheet against the tack-free die-attach adhesive film and placing a tacky dicing tape against the buffer sheet, wherein the buffer sheet preferentially adheres to the tacky dicing tape.

18. The method of claim 17 wherein said excising the semiconductor wafer includes, after dicing the semiconductor wafer, removing the tacky dicing tape and the buffer sheet, wherein the tack-free die-attach adhesive film remains tacked to the individual semiconductor die.

19. The method of claim 17 wherein the buffer sheet is a layer of a sacrificial material having greater adhesion to the tacky dicing tape than to the tack-free die-attach adhesive film.

20. The method of claim 1 wherein the film of tack-free die-attach adhesive includes a tack-free die attach layer and an interlayer, and wherein said placing the film of tack-free die-attach adhesive includes placing the tack-free die-attach layer against a semiconductor wafer.

21. The method of claim 20 wherein said excising the semiconductor wafer includes placing the interlayer of the tack-free die-attach adhesive film against a tacky dicing tape, wherein the interlayer preferentially adheres to the tacky dicing tape.

22. The method of claim 21 wherein said excising the semiconductor wafer includes removing the tacky dicing tape after dicing the semiconductor wafer, wherein the interlayer substantially releases from the tack-free die-attach layer and the tack-free die-attach adhesive film remains tacked to the individual semiconductor die.

23. The first semiconductor die tacked to an electronic substrate by the tack-free die-attach adhesive film according to claim 11 wherein the tack-free die-attach adhesive film includes thermoplastic and thermosetting adhesive resins.

24. A method for making from a semiconductor wafer an individual semiconductor die having a tack-free die-attach adhesive film preform thereon comprising:

providing a film of tack-free die-attach adhesive including thermoplastic and thermosetting resins;

placing the film of tack-free die-attach adhesive against the semiconductor wafer to substantially cover a broad surface thereof;

heating at least the tack-free die-attach adhesive film to a melt-flow temperature and applying pressure thereto to tack the tack-free die-attach adhesive film to the broad surface of the semiconductor wafer; and

excising the semiconductor wafer and the tack-free die-attach adhesive preform tacked thereto into individual semiconductor die each having a portion of the tack-free die-attach adhesive film tacked thereto.

25. The method of claim 24 wherein the tack-free die-attach adhesive is predominantly thermoplastic adhesive having a melt-flow temperature in the range of 100 - 300°C.

26. The method of claim 24 wherein the tack-free die-attach adhesive is predominantly thermosetting adhesive having a melt-flow temperature in the range of 60 - 150°C.

27. The method of claim 24 wherein the tack-free die-attach adhesive is molecularly flexible.

28. The method of claim 24 wherein the film of tack-free die-attach adhesive is self supporting without a supporting film or mesh.

29. The method of claim 24 wherein said tack-free die-attach adhesive is at least one of insulating, electrically conductive, anisotropic electrically conductive and thermally conductive.

30. The method of claim 24 wherein said heating and applying pressure includes laminating the tack-free die-attach adhesive film to the broad surface of the semiconductor wafer using one of a heated lamination press and a pair of heated lamination rollers.

31. The method of claim 30 further comprising placing the semiconductor wafer in a non-stick wafer holder having a recess shaped for holding the semiconductor wafer before said placing the film of tack-free die-attach adhesive against the semiconductor wafer.

32. The method of claim 30 further comprising placing a sheet of release material on the film of tack-free die-attach adhesive before said laminating.

33. The method of claim 24 further comprising heating at least the portion of the tack-free die-attach adhesive film tacked to a first one of the semiconductor die and placing the tack-free die-attach adhesive tacked thereto against an electronic substrate to tack the first semiconductor die thereto.

34. The method of claim 33 further comprising curing the tack-free die-attach adhesive without pressing the semiconductor die against the electronic substrate.

35. The method of claim 33 further comprising heating at least the portion of the tack-free die-attach adhesive film tacked to a second one of the semiconductor die and placing the tack-free die-attach adhesive tacked thereto against the first semiconductor die to tack the first semiconductor die thereto.

36. The method of claim 24 wherein said providing a film of tack-free die-attach adhesive includes providing a tack-free die-attach adhesive preform including a pattern of individual tack-free die-attach adhesive preforms on a release liner, wherein the pattern of individual tack-free die-attach adhesive preforms corresponds to a pattern of individual electronic circuits on the broad surface of the semiconductor wafer and has spaces between the individual tack-free die-attach adhesive preforms corresponding to excising spaces of the semiconductor wafer.

37. The method of claim 24 wherein said excising the semiconductor wafer includes placing a buffer sheet against the tack-free die-attach adhesive film and placing a tacky dicing tape against the buffer sheet, wherein the buffer sheet preferentially adheres to the tacky dicing tape.

38. The method of claim 37 wherein said excising the semiconductor wafer includes, after dicing the semiconduetor wafer, removing the tacky dicing tape and the buffer sheet, wherein the portion of the tack-free die-attach adhesive film remains tacked to the individual semiconductor die.

39. The method of claim 37 wherein the buffer sheet is a layer of a sacrificial material having greater adhesion to the tacky dicing tape than to the tack-free die-attach adhesive film.

40. The method of claim 24 wherein the film of tack-free die-attach adhesive includes a tack-free die attach layer including thermoplastic and thermosetting resins and a sacrificial layer, and wherein said placing the film of tack-free die-attach adhesive includes placing the tack-free die-attach layer against a semiconductor wafer.

41. The method of claim 40 wherein said excising the semiconductor wafer includes placing the sacrificial layer of the tack-free die-attach adhesive film against a tacky dicing tape, wherein the sacrificial layer preferentially adheres to the tacky dicing tape.

42. The method of claim 41 wherein said excising the semiconductor wafer includes removing the tacky dicing tape after dicing the semiconductor wafer, wherein the sacrificial layer substantially releases from the tack-free die-attach layer and the tack-free die-attach adhesive film remains tacked to the individual semiconductor die.

43. The first semiconductor die tacked to an electronic substrate by the tack-free die-attach adhesive film including thermoplastic and thermosetting adhesive resins according to claim 33.

44. A method for making from a semiconductor wafer an individual semiconductor die having a tack-free die-attach adhesive film preform thereon comprising:

providing a thin film of tack-free die-attach adhesive including thermoplastic adhesive resin and thermosetting adhesive resin;

placing the film of tack-free die-attach adhesive against the semiconductor wafer to substantially cover a broad surface thereof;

placing a sheet of release material over the film of tack-free die-attach adhesive on the semiconductor wafer;

laminating the tack-free die-attach adhesive film to the broad surface of the semiconductor wafer by applying heat and pressure effective to melt flow the tack-free die-attach adhesive film without significantly curing the thermosetting adhesive resin; and

excising individual semiconductor die each having a portion of the tack-free die-attach adhesive film tacked thereto from the semiconductor wafer having the tack-free die-attach adhesive preform tacked thereto.

45. A method for making from a semiconductor wafer an individual semiconductor die having a tack-free die-attach adhesive film preform thereon comprising:

providing a thin film of tack-free die-attach adhesive including a first layer of thermoplastic adhesive resin and thermosetting adhesive resin and a sacrificial layer;

placing the first layer of the film of tack-free die-attach adhesive against the semiconductor wafer to substantially cover a broad surface thereof;

laminating the tack-free die-attach adhesive film to the broad surface of the semiconductor wafer by applying heat and pressure effective to melt flow the tack-free die-attach adhesive film without significantly curing the thermosetting adhesive resin;

placing the sacrificial layer of the tack-free die-attach adhesive film against a tacky dicing tape; and

excising individual semiconductor die each having an excised portion of the first layer of the tack-free die-attach adhesive film tacked thereto from the semiconductor wafer, wherein the sacrificial layer preferentially adheres to the tacky dicing tape.

46. The method of claim 45 wherein said excising the semiconductor wafer includes removing the individual semiconductor die from the tacky dicing tape after dicing the semiconductor wafer, wherein the sacrificial layer substantially releases from the first layer and the first layer remains tacked to the individual semiconductor die.

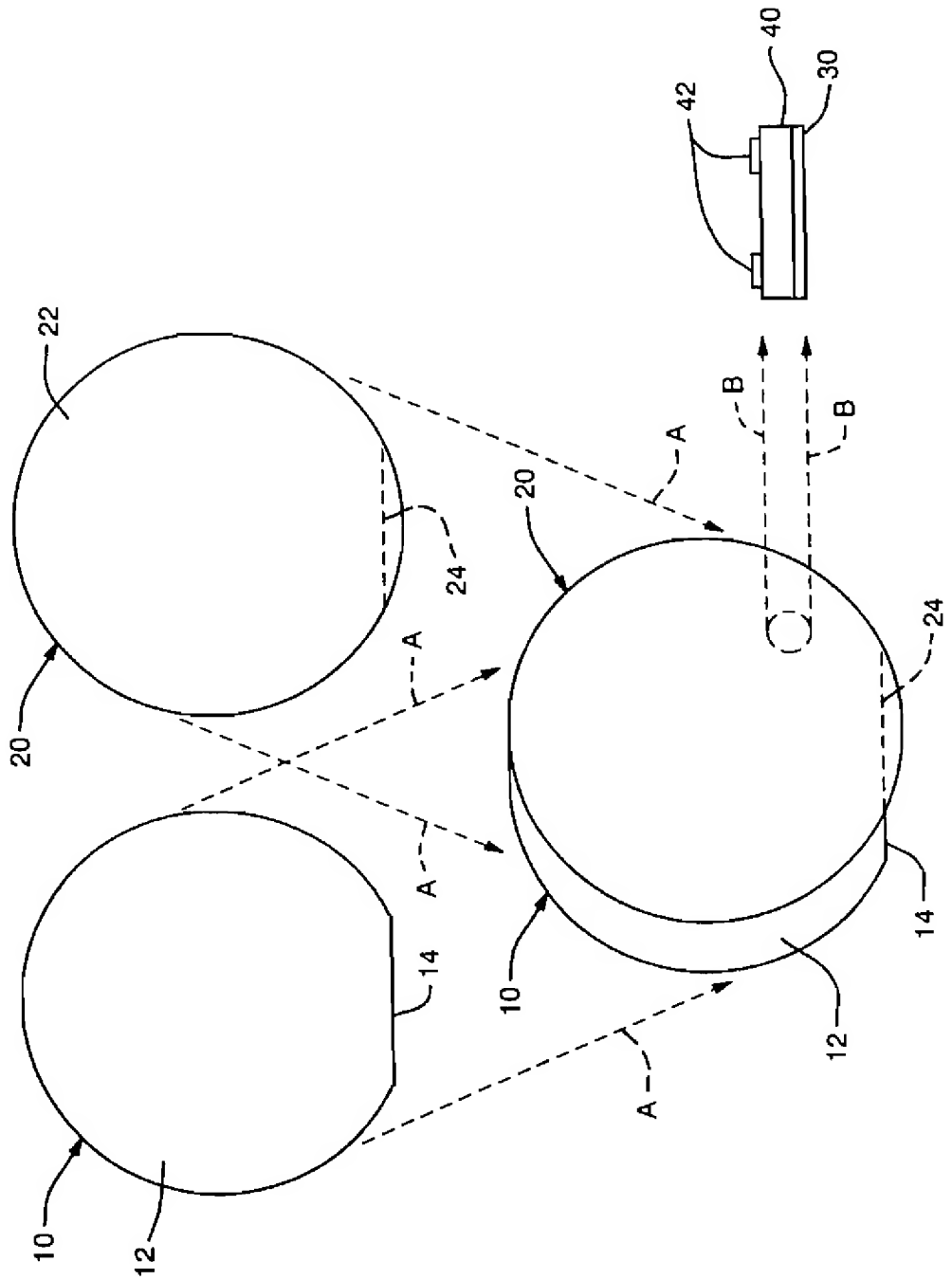


FIG. 1A

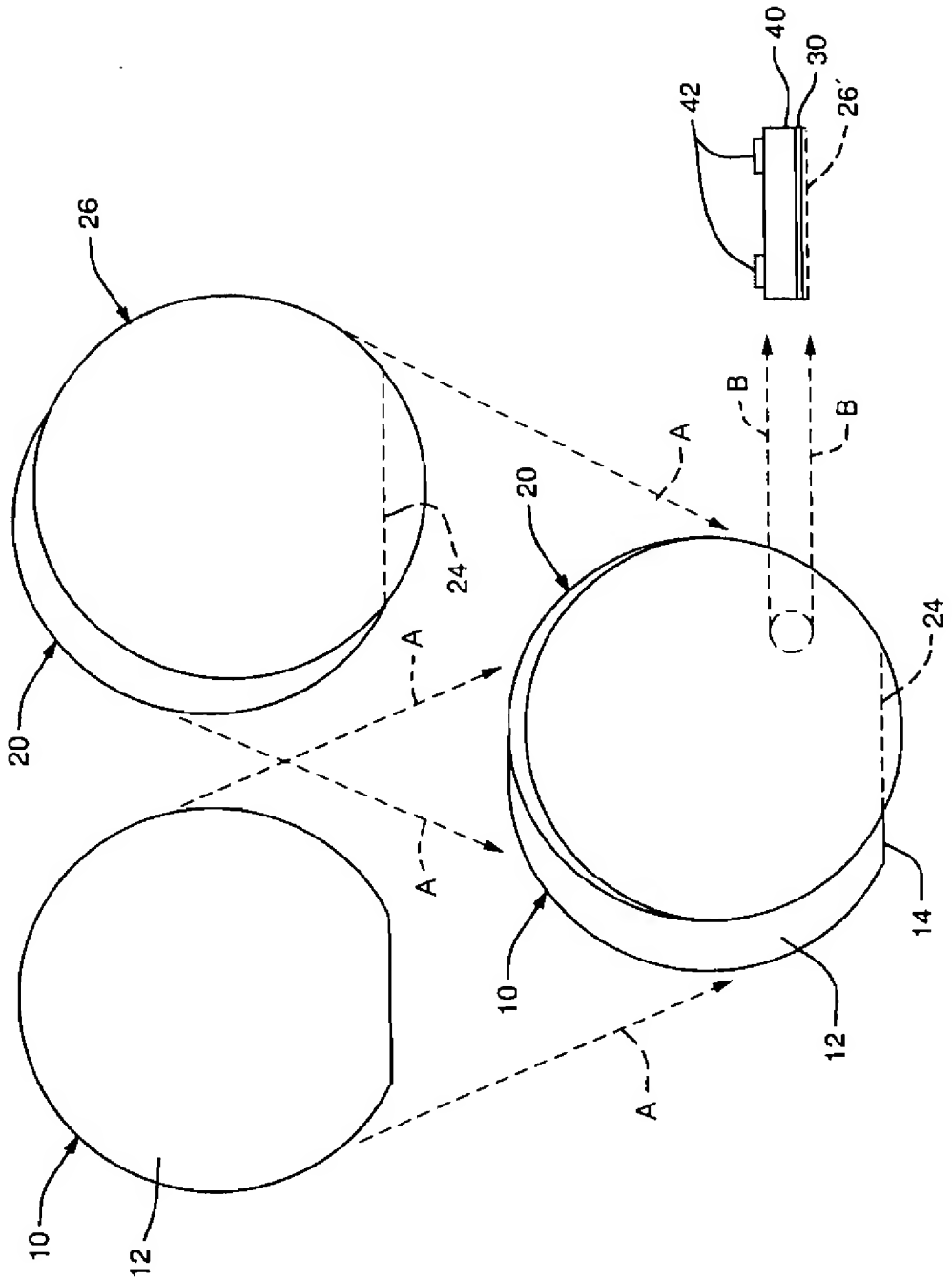


FIG. 1B

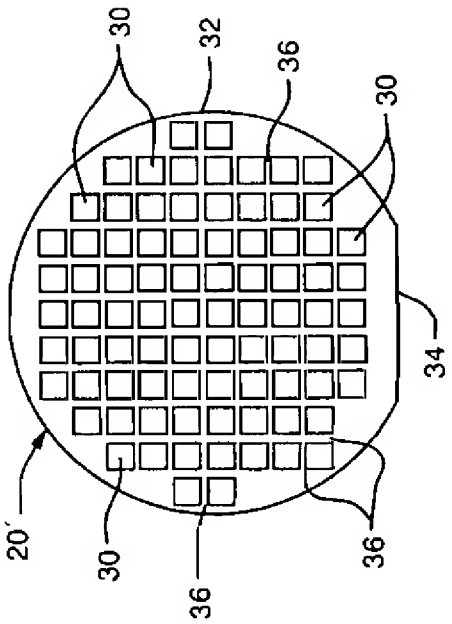


FIG. 2

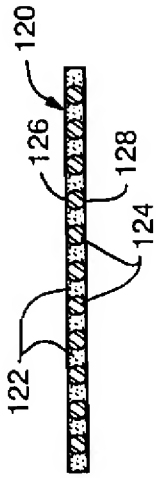


FIG. 3B

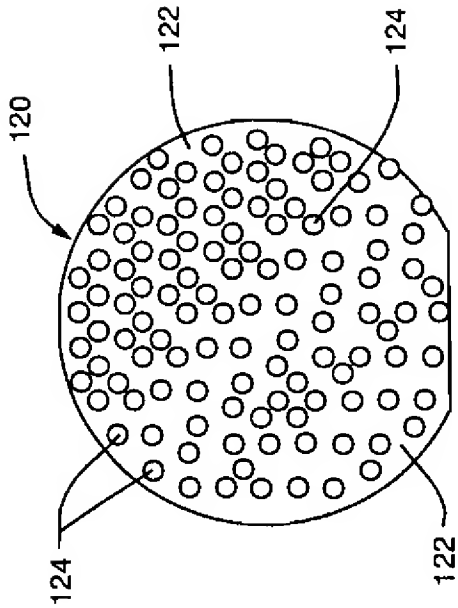


FIG. 3A

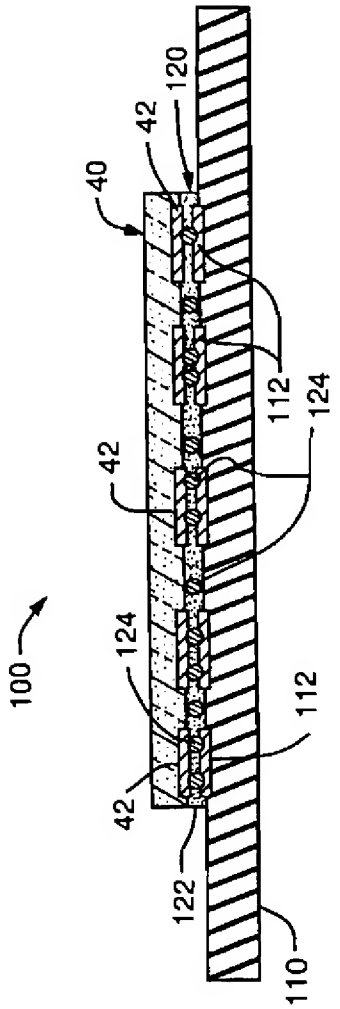
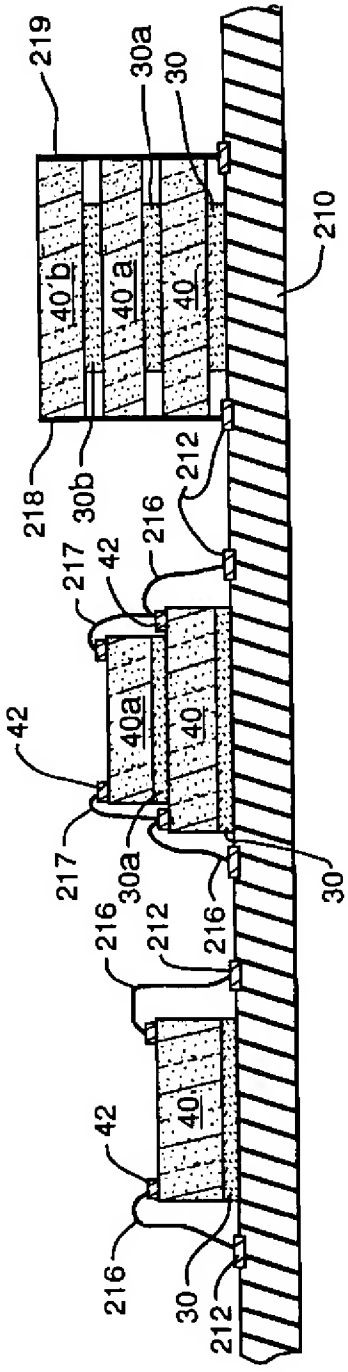


FIG. 4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40 b
40 a
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218
30b
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30a
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42
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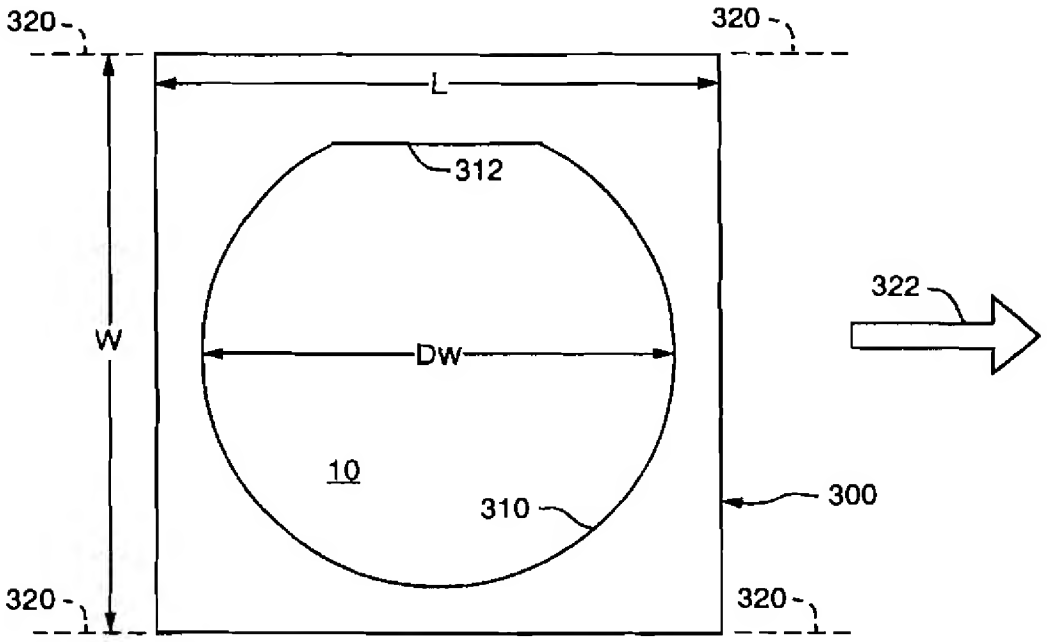
216
30
212

FIG. 5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320
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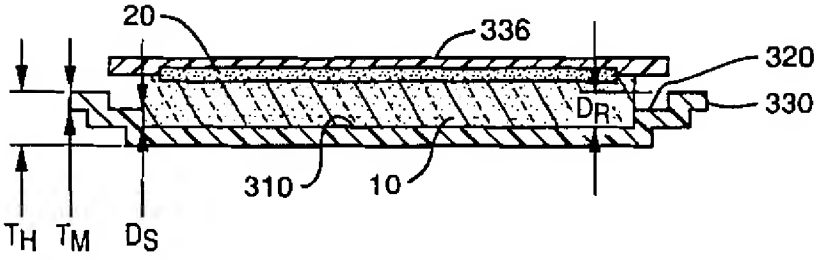
322
W
Dw
10
310
300
320
320

FIG. 6A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10
TH
TM
DS

FIG. 6B

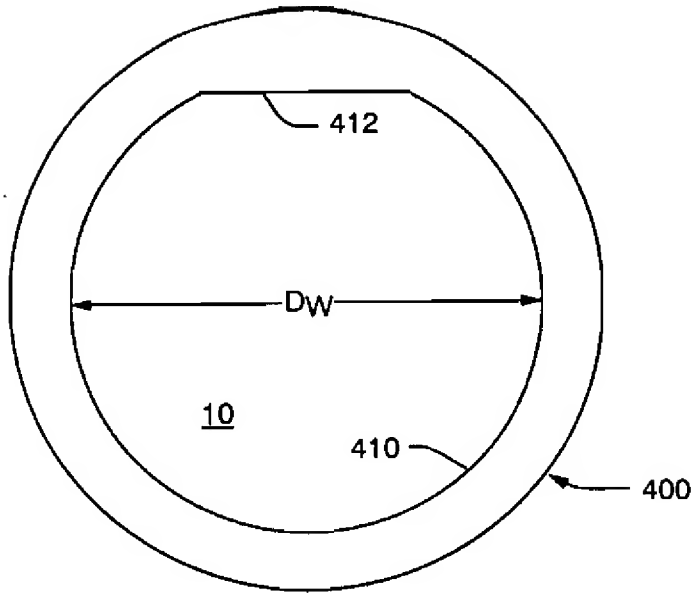

FIG. 7

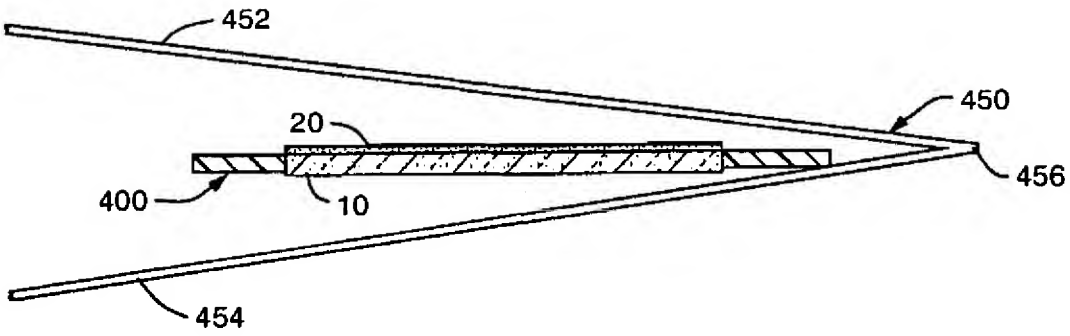

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/30506

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H01L 21/44, 21/48, 21/50, 21/46, 21/78, 21/301, 23/48, 23/52, 29/40
US CL : 438/114, 118, 119, 460, 465, 387; 257/783

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 438/114, 118, 119, 460, 465, 387; 257/783

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,590,667 A (SIMONS) 05 May 1986 (05.05.1986), entire document.	
A	JP 59-98537 A (NEC CORP.) 06 June 1984 (06.06.1984), entire document.	

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 February 2001 (20.02.2001)	04 APR 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer David E Graybill Telephone No. 703-308-1782

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/30506

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claim Nos.: 1-46
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
See attached

3. ☐ Claim Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest
☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/30506

Continuation of Box I Reason 2:

Claims 1-46 have not been rejected over the prior art because there is a great deal of confusion and uncertainty as to the proper interpretation of the limitations of the claims; hence, it would not be proper to reject the claims on the basis of prior art. Therefore, the cited references are applied to the specification disclosure.